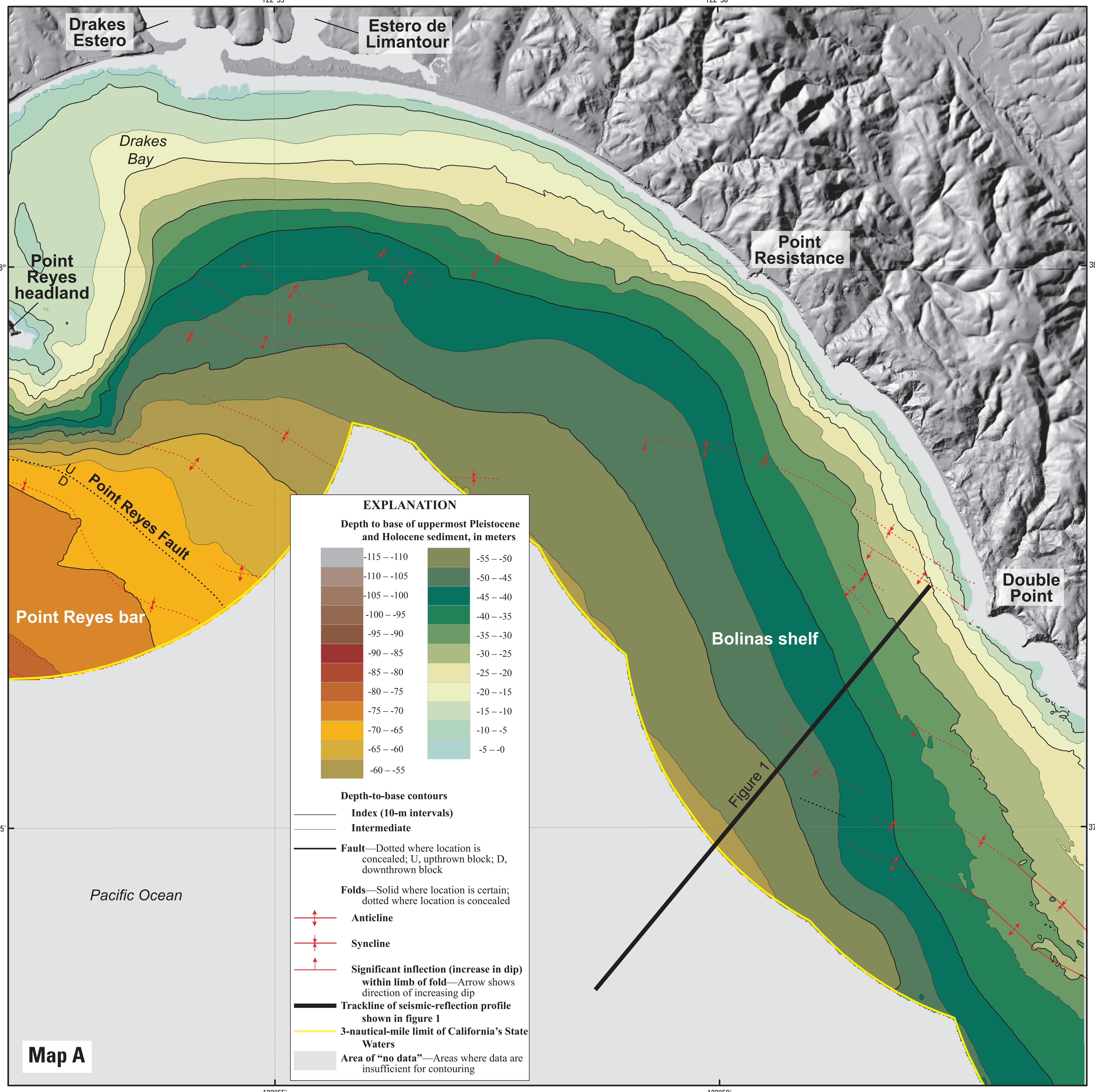
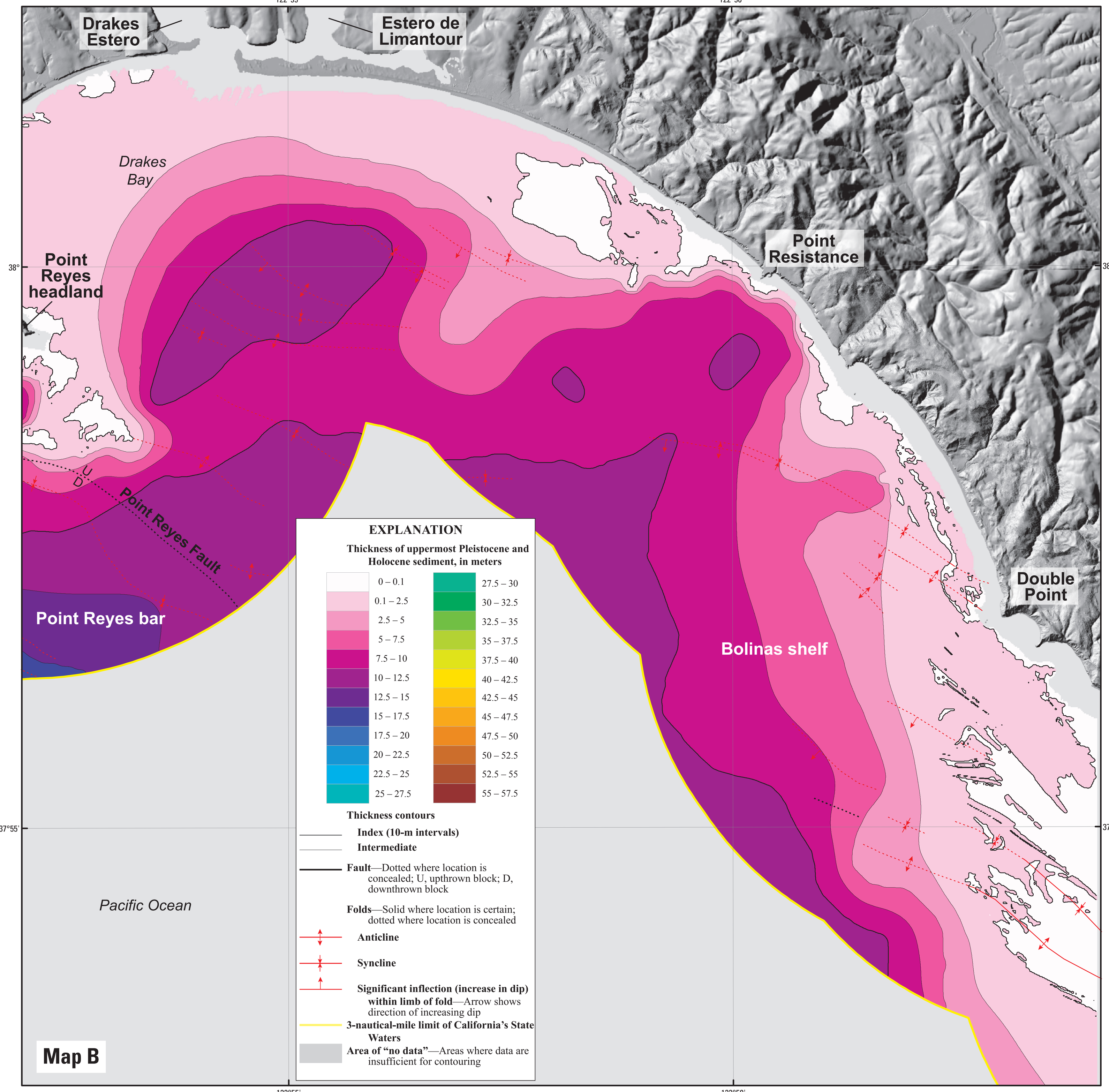
U.S. Department of the Interior
U.S. Geological Survey

Open-File Report 2015–1041
Sheet 9 of 10
Pamphlet accompanies map





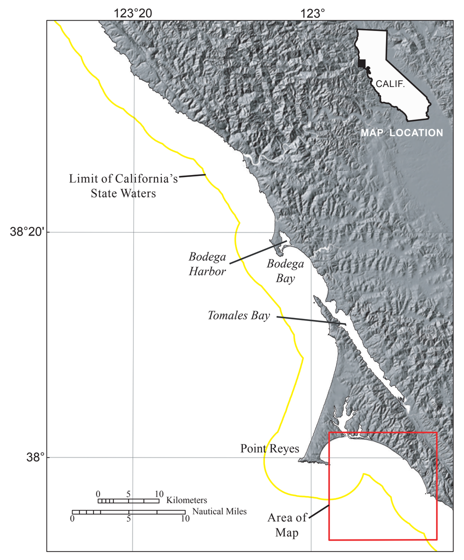
Onshore elevation data from U.S. Geological Survey's National Elevation Dataset (available at http://ned.usgs.gov/). California's State Waters limit from NOAA Office of Coast Survey

Universal Transverse Mercator projection, Zone 10N

APPROXIMATE MEAN DECLINATION, 2015

Depth and thickness mapped by Janet T. Watt, Samuel Y. Johnson, and Steven R. Hartwell, 2012-2013

GIS database and digital cartography by Stephen R. Hartwell



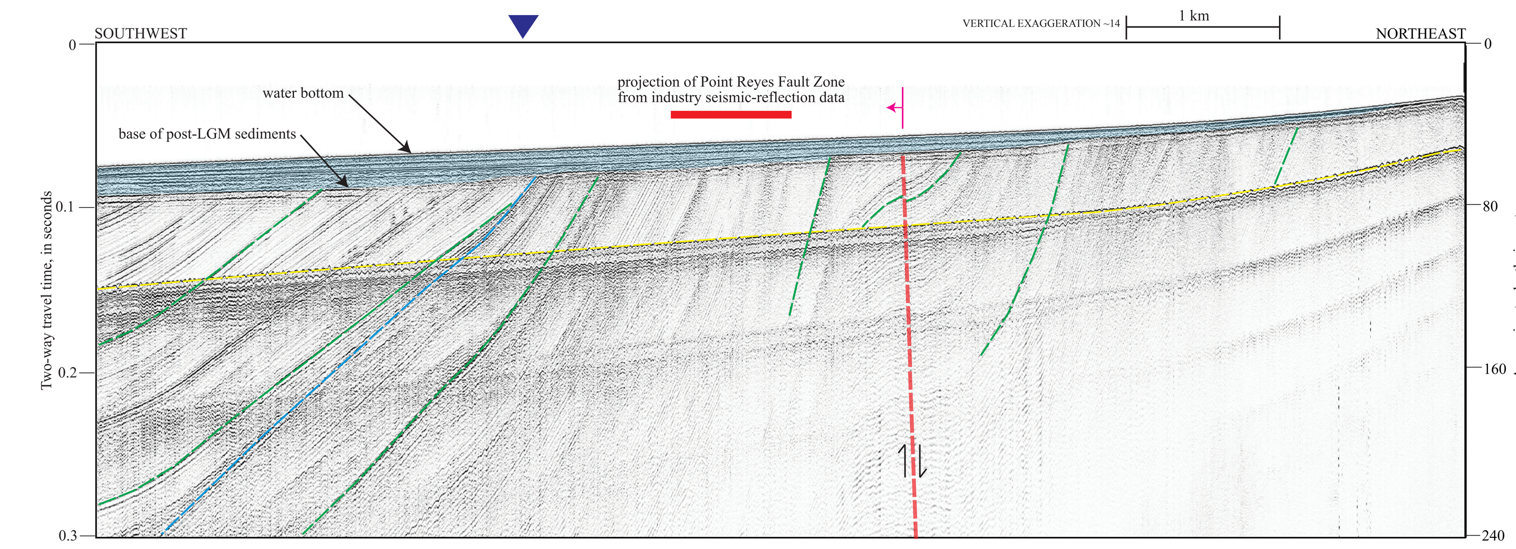


Figure 1. USGS high-resolution minisparker seismic-reflection profile PR–33 (collected in 2009 on survey S–8–09–NC), which crosses shelf southwest of Double Point (see Map A for location). Profile shows southwest-dipping reflectors that represent Tertiary strata deposited along eastern margin of Bodega Basin (see fig. 5 on sheet 8). Dashed red line shows fault; black arrows on fault show relative motion. Magenta symbol shows sharp flexure (arrow shows direction of increasing dip). Blue shading shows inferred uppermost Pleistocene and Holocene shelf strata, deposited since last sea-level lowstand about 21,000 years ago. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed blue line shows erosional unconformity. Dashed yellow line is seafloor multiple (echo of seafloor reflector). Purple triangle shows location of California's State Waters limit (yellow line on Map A).

DISCUSSION

This sheet includes maps that show the interpreted thickness and the depth to base of uppermost Pleistocene and Holocene deposits in California's State Waters for the Drakes Bay and Vicinity map area (Maps A, B), as well as for a larger area that extends about 115 km along the coast from Salt Point to Drakes Bay on the south flank of the Point Reyes peninsula (Maps C, D, E) to establish regional context. This uppermost stratigraphic unit (blue shading in seismic-reflection profile of fig. 1; see also, figs. 1, 2, 3, 4, 6, 8, 10 on sheet 8) is inferred to have been deposited during the post–Last Glacial Maximum (LGM) sea-level rise in the last about 21,000 years (see, for example, Peltier and Fairbanks, 2006; Stanford and others, 2011). The unit commonly is characterized either by "acoustic transparency" or by parallel, low-amplitude, low- to high-frequency, continuous to moderately continuous, diffuse reflections (terminology from Mitchum and others, 1977). The acoustic transparency can be caused by extensive wave winnowing, which results in a uniform sediment grain size and the consequent lack of acoustic-impedance contrasts needed to produce seismic reflections. On the continental shelf, the contact with underlying units is a transgressive surface of erosion commonly marked by angularity, channeling, or a distinct upward change to lower amplitude, more diffuse reflections.

Offshore of Salt Point, about 75 km north of the Drakes Bay and Vicinity map area, the sequence of uppermost Pleistocene and Holocene deposits, which lies above a prominent unconformity, includes a lower, older stratigraphic unit made up of a downlapping sediment wedge that formed along the southwest flank of nearshore bedrock outcrops. Stratigraphic position, depth of occurrence, and reflection geometry suggest that this lower unit formed during the latter stages of the pre-LGM sea-level fall (about 30,000 to 21,000 years ago). Our regional thickness and depth-to-base maps (Maps C, D) combine these two uppermost Pleistocene and Holocene units in this northern part of the Salt Point to Drakes Bay region.

To make these maps, water bottom and depth to base of the post-LGM horizons were mapped from seismic-reflection profiles (fig. 1; see also, sheet 8). The difference in the two horizons was exported for every shot point as XY coordinates (UTM zone 10) and two-way travel time (TWT). The thickness of the post-LGM unit (Maps B, D) was determined by applying a sound velocity of 1,600 m/sec to the TWT. The thickness points were interpolated to a preliminary continuous surface, overlaid with zero-thickness bedrock outcrops (see sheet 10), and contoured, following the methodology of Wong and others (2012).

The thickness data points are dense along tracklines (about 1 m apart) and sparse between tracklines (1 km apart), resulting in minor contouring artifacts. To incorporate the effect of a few rapid thickness changes along faults, to remove irregularities from interpolation, and to reflect other geologic information and complexity, minor manual editing of the preliminary thickness contours was undertaken. Contour modifications and regridding were repeated several times to produce the final sediment-thickness maps. Information for the depth to base of the post-LGM unit (Maps A, C) was generated by adding the sediment-thickness data to water depths determined by multibeam bathymetry (see sheet 1).

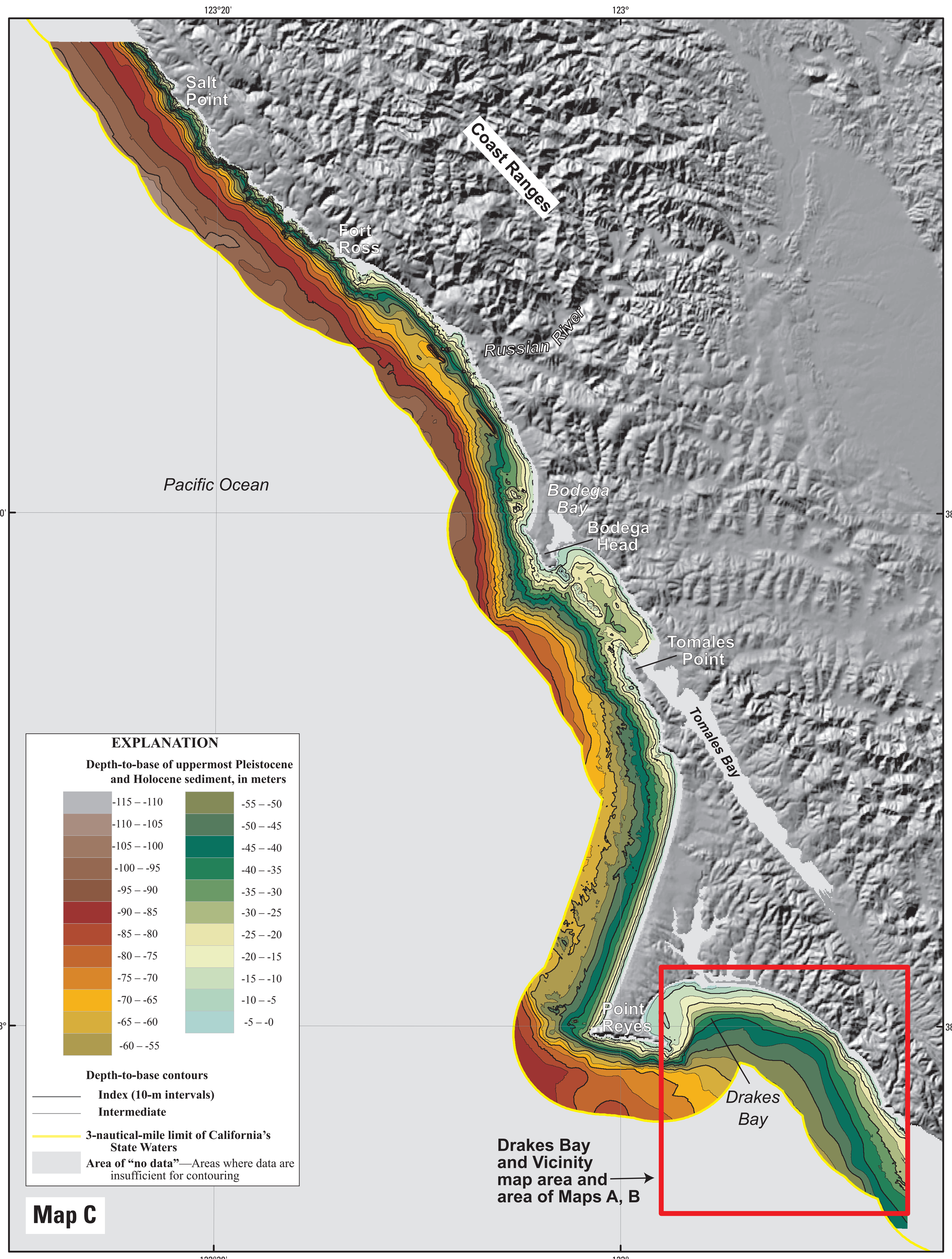
The thickness of the post-LGM unit in the Drakes Bay and Vicinity map area ranges from 0 to 15 m (Map B), and the depth to base of the unit ranges from 0 to 80 m (Map A). Mean sediment thickness for the map area is 6.0 m, and total sediment volume is 852×10^6 m^3. In general, the thickness of the post-LGM unit increases offshore where finer grained sediment is derived either locally from Drakes Estero and Estero de Limantour or from San Francisco Bay to the south (about 30 km south of the map area). The input of sand to the beaches within Drakes Bay is limited to that from local sources (cliff erosion) and from transport from around the Point Reyes headland; the estimated long-term (mid- to late-1800s to 1902) rate of erosion of the beach at Limantour Spit is -0.5 m/yr (Hapke and others, 2006).

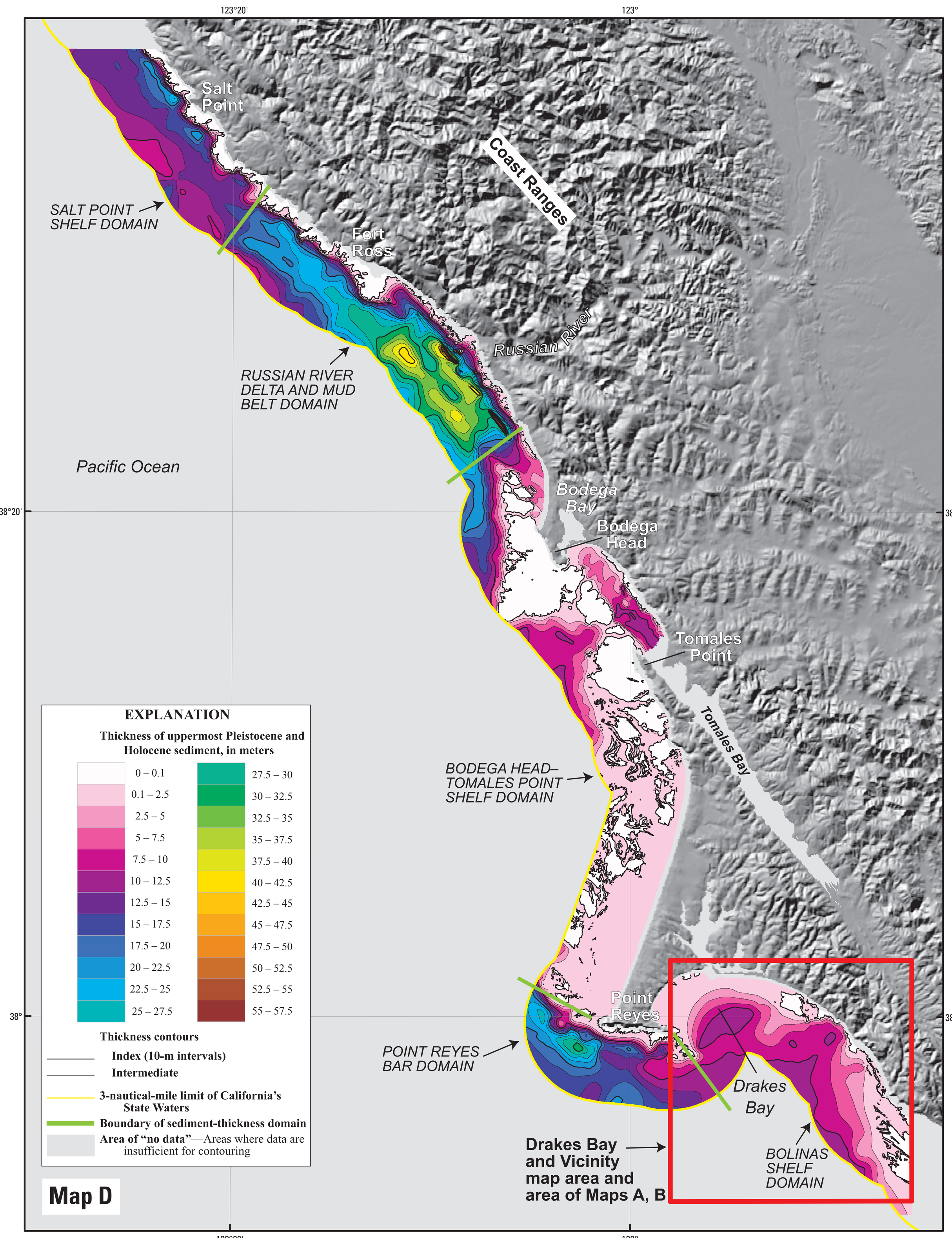
The thickest deposits are found at water depths of about 60 to 70 m where nearshore-bar deposits overlie deeper water deposits in what is referred to as the Point Reyes bar (Map B). The nearshore-bar deposits are characterized by low-amplitude, prograding clinoforms, which are visible in high-resolution seismic profiles. The Point Reyes bar likely formed in the lee of the Point Reyes headland during rising sea level. These nearshore deposits overlie parallel, gently seaward-dipping reflectors (see sheet 8), which likely were deposited in deeper water (below wave base). In addition, a depocenter present within Drakes Bay (offshore of Drakes Estero and Estero de Limantour) is bounded on the south by an east-northeast-trending ridge on the Bolinas shelf, west of Point Resistance (Map B). Southeast of Drakes Bay, Neogene sedimentary rocks either crop out on the seafloor or are buried by only a thin cover (mostly less than 2.5 m) of uppermost Pleistocene and Holocene sediment.

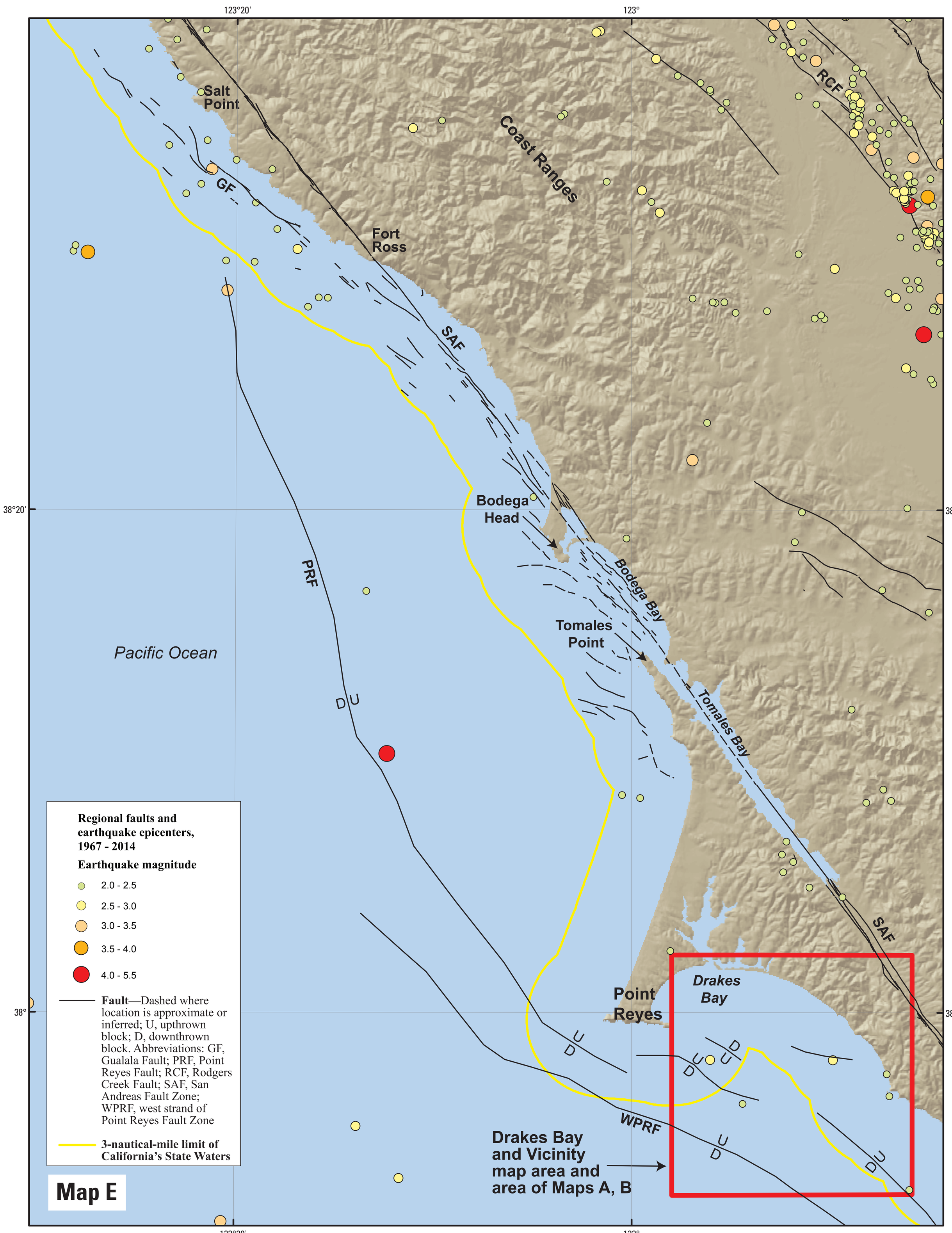
The relatively thin post-LGM sediment cover in the southeastern part of the map area is related to both active uplift and a limited sediment supply. Active uplift, which is recorded in marine terraces along the southern part of the Point Reyes peninsula, is a result of the complex interactions between the Point Reyes, San Gregorio, and San Andreas Faults (Grove and Ryan, 2007; Grove and others, 2010). The Point Reyes bar and Drakes Bay trap most of the littoral sediment supply transported from the north. In addition, west-facing coastal watersheds in this part of the Point Reyes peninsula are very small, and so much of the meager sediment that is present on the southern part of the Bolinas shelf likely is derived from local erosion of coastal bluffs or from northward transport of sediment from San Francisco Bay.

Five different "domains" of sediment thickness are recognized on the regional sediment-thickness map (Map D), each with distinctive geologic controls: (1) The Salt Point shelf domain, located in the far northwestern part of the region, has a mean sediment thickness of 11.7 m. The thickest sediment (20 to 25 m) is found where a pre-LGM, regressive, downlapping sediment wedge formed above a break in slope that is controlled by a contact between harder bedrock and softer, folded Pleistocene strata. Sediment thinning in this domain within the outer parts of California's State Waters is the result of a relative lack of sediment supply from local watersheds, as well as a more distal Russian River source. (2) The Russian River delta and mud belt domain, located offshore of the Russian River, the largest sediment source on this part of the coast, has the thickest uppermost Pleistocene and Holocene sediment in the region (mean thickness, 21.1 m). The northward extension into the midshelf "mud belt" results from northward shelf-bottom currents and sediment transport (Drake and Cacchione, 1985). This domain includes a section of the San Andreas Fault Zone, which here is characterized by several releasing, right-stepping strands that bound narrow, elongate pull-apart basins; these sedimentary basins contain the greatest thickness of uppermost Pleistocene and Holocene sediment (about 56 m) in the region. (3) The Bodega Head–Tomales Point shelf domain, located between Bodega Head and the Point Reyes headland, contains the least amount of sediment in the region (mean thickness, 3.4 m). The lack of sediment primarily reflects decreased accommodation space (note shallower depth contours on Maps A, C) and limited sediment supply. (4) The Point Reyes bar domain, located west and south of the Point Reyes headland, is a local zone of increased sediment thickness (mean thickness, 14.3 m) created by bar deposition on the more protected south flank of the Point Reyes headland during rising sea level. (5) The Bolinas shelf domain, located east and southeast of the Point Reyes headland (including most of the Drakes Bay and Vicinity map area), has a thin sediment cover (mean thickness, 5.6 m), which likely reflects limited sediment accommodation space caused by tectonic uplift (water depths in this domain within California's State Waters are less than 45 m), as well as the limited sediment supply and the high wave energy capable of reworking and transporting shelf sediment to deeper water.

Map E shows the regional pattern of major faults and of earthquakes occurring between 1967 and April 2014 that have inferred or measured magnitudes of 2.0 and greater. Fault locations, which have been simplified, are compiled from our mapping within California's State Waters (see sheet 10) and from the U.S. Geological Survey's Quaternary fault and fold database (U.S. Geological Survey and California Geological Survey, 2010). Earthquake epicenters are from the Northern California Earthquake Data Center (2014), which is maintained by the U.S. Geological Survey and the University of California, Berkeley, Seismological Laboratory. The largest earthquake in the map area (M2.9, 4/13/1970) was located about 3.8 km southeast of the Point Reyes headland. A notable lack of microseismicity on the adjacent San Andreas Fault has occurred since the devastating great 1906 California earthquake (M7.8, 4/18/1906), thought to have nucleated on the San Andreas Fault offshore of San Francisco (see, for example, Bolt, 1968; Lomax, 2005), about 30 km south of the map area.







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Local (Drakes Bay and Vicinity Map Area) and Regional (Offshore from Salt Point to Drakes Bay) Shallow-Subsurface Geology and Structure, California

By

Janet T. Watt, Samuel Y. Johnson, Stephen R. Hartwell, and Ray W. Sliter

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